METHOD FOR PREPARING VIRUS-SAFE PHARMACEUTICAL COMPOSITIONS

Background of the Invention

Field of the Invention

The present invention relates to the preparation of virus-safe pharmaceutical compositions of biologically active proteins. In particular, the present invention concerns a method for preparing a virus-safe, liquid formulation of α-interferon, preferably multicomponent α-interferon, having extended shelf-life. The present invention also relates to the use of non-ionic detergents as stabilizers of pharmaceutical compositions and to virus-safe multi-component α-interferon solutions which can be used as injectables in the treatment of diseases.

Description of Related Art

Pharmaceutical compositions of biologically active proteins must be virus-safe, i.e. they must be free from any contaminating, potentially pathogenic viruses and other infectious agents. Further, such pharmaceutical compositions should have extended shelf-life providing for their use over a prolonged period of time. In the following, the questions of virus-safety and shelf-life of proteineous pharmaceutical compositions will be discussed with particular reference to interferon formulations. However, the principles are generally applicable to physiologically active substance originating from human or animal blood, urine or internal organs and to corresponding recombinant proteins produced in cultured animal cells or transgenic animals.

Human alpha-interferons (IFN-α) comprise a family of closely related proteins with antiproliferative, antiviral and immunomodulatory effects. Human leukocytes and lymphoblastoid cells are known to produce several IFN-α subtypes in culture when induced by Sendai virus (Cantell et al., Methods Enzymol. 78, 29-38, 1981, Mizrani, Methods Enzymol. 78. 54-68, 1981). Purified multicomponent IFN-α drugs are used in the treatment of various diseases, including neoplastic and viral diseases. It has been shown in the art that multicomponent IFN-α drugs have therapeutic benefits in comparison with recombinant IFN-α drugs produced in bacteria, which only contain a single IFN-α subtype.

Commercial production of human multicomponent IFN-α comprises culturing human leukocytes or lymphoblastoid cells and inducing them with Sendai virus. These products therefore carry a risk of virus contamination. Blood-borne viruses potentially present in leukocytes and serum or its fractions used in the culture medium include HI-viruses, hepatitis C and B viruses and small non-enveloped viruses, such as parvovirus B19, which is resistant to many physicochemical treatments. Lymphoblastoid cell lines may harbour e.g. retroviruses. Production of IFN-α and other biologically active proteins in animal cell cultures or in transgenic animals also carries a risk of viral contamination.

An effective method for the removal of viruses of diverse physicochemical properties is filtration with membranes with high virus retentive capacities, also known as nanofiltration or virus filtration. The particular advantage of filtration is that it will also remove viruses, such as non-enveloped viruses, and other infectious agents, such as those causing transmissible spongiform encephalopathies ("prions"), which exhibit resistance to conventional treatments based on the use of heat and chemicals (physicochemically resistant agents).

In order to prevent the binding of biologically active proteins, such as IFN-α, to filters, final containers and other surfaces, stabilizers are typically added to solutions containing the purified biologically active protein. In addition to the above short-term stabilizing effect, stabilizers will also prevent aggregation of the proteins and, thus, provide extended shelf-life. Albumin is the most common stabilizer used, e.g., in multicomponent IFN-α products and it is employed in many of the commercial preparations (Alfanative®, Alferon® N, Wellferon®).

However, the use of albumin as a stabilizer in IFN-α products may cause at least two problems. First, albumin has been reported to result in the formation of albumin-IFN aggregates in the product, which may be antigenic and result in the formation of antibodies against IFN-α (Braun et al., Pharm. Res. 14, 1472-1478, 1997). These problems have been identified with bacterial recombinant IFN-α products. Second, and importantly as regards the preparation of virus-safe formulations, if the formulated IFN-α solution is to be filtrated with a virus removal filter, as is the case for IFN-α compositions produced in human or animal cells or in transgenic animals, the use of albumin as a stabilizer decreases the ability of the filter to remove viruses, since it has been shown that virus removability of a virus removal filter decreases with increasing concentration of coexisting protein (Hirasaki et al., Membrane 20, 135-142, 1995). This is evidently caused by plugging of the

filter with coexisting protein which is reflected as decreasing filtration rate when pressure is kept constant. As Example 2 below shows, the filtration rate dropped by about 80 % after filtration of 20 l/m^2 of a highly purified IFN-α solution containing 1 g/l albumin.

It is known in the art that certain proteins, in particular human growth hormone, can be prevented from adsorbing onto a membrane filter by pretreating the filter with human serum albumin or with polyvinylpyrrolidone, polyoxyethylene sorbitan monolaurate, polysorbate 80, modified gelatin and gelatin (US Patent No. 5,173,415). This known pretreatment comprises adsorbing albumin or another of the listed substances to the filter from an aqueous solution by filtration, impregnation or soaking.

Although said treatment may have some beneficial effect on the filtration rate, it constitutes an additional, cost-consuming step. Furthermore, the coating of the filter with albumin will not reduce adsorption of the proteins to other surfaces being in contact with the product, such as tubing, collecting vessels, vials and stoppers.

Summary of the Invention

It is an object of the present invention to eliminate the problems of the prior art and to provide a novel method of preparing virus-safe pharmaceutical compositions of biologically active proteins.

It is another object of the invention is to provide a new use of non-ionic detergents as stabilizers for liquid formulations of biologically active proteins, such as IFN-α, which can be filtered with a virus removal filter with improved yield and capacity and used as injectables.

It is a third object of the present invention to provide a novel liquid formulation of multi-component IFN-α, which does not contain polymers of IFN-α or albumin-IFN complexes, which exhibits prolonged shelf-life and which can be used as an injectable.

These and other objects, together with the advantages thereof over known processes, which shall become apparent from specification which follows, are accomplished by the invention as hereinafter described and claimed.

The present invention is based on the finding that by using a non-ionic detergent as a

stabilizer of pharmaceutical compositions comprising biologically active proteins and by adding said stabilizer to the formulation before virus filtration, the yield and capacity of virus filtration can be greatly increased. This finding was surprising since it is known that non-ionic surfactants, like polysorbate 80, have very low critical micelle concentrations (CMC). Thus, the CMC of for example polysorbate 80 is ca. 0.013 g/l in aqueous solutions (Helenius and Simons, Biochim. Biophys. Acta 415, 29-79, 1975). Above the CMC, non-ionic surfactants form micelles with varying sizes, which penetrate very slowly e.g. dialysis membranes.

According to the present invention, non-ionic detergents (surfactants) are added to pharmaceutical compositions in concentrations above the CMC before virus removal filtration to provide stabilized proteineous formulations, for example multicomponent IFN-α formulations, which are essentially free from substances (including viruses and prions) having a size in excess of 10 to 40 nm, in particular 10 to 20 nm, and normally being retained on a virus filter.

In particular, the present method for preparing virus-safe pharmaceutical compositions of biologically active proteins is characterized by what is stated in the characterizing part of claim 1.

The method for stabilizing pharmaceutical compositions of purified leukocyte α- interferon is characterized by what is stated in the characterizing part of claim 13 and the virus-safe α-interferon solution is characterized by what is stated in the characterizing part of claim 15.

The invention provides considerable advantages. Thus, a multicomponent IFN-α solution stabilized according to the present invention with a non-ionic detergent exhibits improved stability. Further, multicomponent IFN-α formulations stabilized with a non-ionic detergent do not contain albumin-IFN complexes, which are formed in albumin-containing formulations and are suggested to be harmful in recombinant IFN-α products. By replacing albumin with a non-ionic detergent as a stabilizer, an IFN-α solution can be filtered with a virus removal filter without plugging of the filter. In other words, by substituting a non-ionic detergent for albumin, it is possible to filter IFN-α solution with improved yield and capacity with a virus removal filter. In comparison to the method known from US Patent No. 5,173,415, the present invention not only increases the yield of filtration, it also prevents losses caused by adsorption of protein from the filtrate to other surfaces being in

contact with the product, such as tubing, collecting vessels, vials and stoppers. By incorporating the non-ionic detergent in the composition before filtering, no pretreatment of the filter is necessary. In fact, test have shown, that such a pretreatment will not improve the yield to any discernible extent.

Next, the invention will be examined more closely with the aid of the following detailed description and with reference to a number of working examples.

Brief Description of the Drawings

In the attached drawings,
Figure 1 shows the adsorption of IFN-α to glass in the presence of different stabilizers;
Figure 2 shows the occurrence of albumin-IFN complexes in solutions stabilized with albumin and the lack of aggregates in solutions stabilized with polysorbate 80;
Figure 3 depicts the virus filtration flow rates of purified IFN-α solutions stabilized by polysorbate 80 and albumin, respectively.

Detailed Description of the Invention

According to the present invention, a non-ionic detergent is added to a solution of purified biologically active protein, which is subsequently filtered with a virus removal filter having a pore size of about 10 to 40 nm and then optionally sterile filtered to obtain a virus-safe, sterile and stable protein solution.

The scope of biologically active proteins covered by the present invention extends to all therapeutically used proteins which may harbour viruses and which are filtered with a virus removal filter. Such proteins generally have a molecular weight of less than 180,000 D and include coagulation factors and their activated forms (e.g. factor IX, factor VII), proteinases, their activated forms and proteinase inhibitors (e.g. protein C), growth factors and colony stimulating factors (e.g. IGF-1, G-CSF, GM-CSF), neurotrophic factors (e.g. NGF, GDNF, NT-3), hormones (e.g. erythropoietin, growth hormone) and other proteins modifying the biological response of cells (e.g. interferons and interleukins). Not only naturally occurring proteins should be considered but also recombinant proteins produced in cultured animal cells or transgenic animals.

The use of non-ionic detergents in various pharmaceutical compositions is known *per se*. It

has also been suggested in the art to use polysorbate 80 instead of albumin as a stabilizer of a recombinant IFN-α2a product in order to prevent formation of albumin-IFN aggregates (Hochuli, J. Interferon Cytocine Res. 17, Suppl. 1, S15-S21, 1997). Liquid α- and γ-interferon compositions containing non-ionic detergents are also disclosed in EP Patent Application No. 0 736 303 A2 and WO 89/04177. However, all the citations are completely silent about the incorporation of a non-ionic detergent into a pharmaceutical composition prior to virus-filtration.

According to a preferred embodiment of the present invention, non-ionic detergents are used as stabilizers of multicomponent IFN-α formulations subjected to virus filtration for removing any agents retained on filters having a pore size of 10-40 nm. These compositions comprise purified leukocyte and lymphoblastoid interferons containing two or more of the following IFN-α subtypes: α1, α2, α4, α7, α8, α10, α14, α17 and α21. Human leukocyte interferon has been shown to contain at least nine IFN-α subtypes (Nyman et al., Biochem. J. 329, 295-302, 1998), and lymphoblastoid interferon contains the same or similar subtypes (Zoon et al., J. Biol. Chem. 267, 15210-15216, 1992). Part of the subtypes secreted by the producer cells may be lost during purification, depending on the purification process employed (US Patent 5,503,828).

Methods for the production of multicomponent IFN-α have been described in detail before. Multicomponent IFN-α can be produced in leukocyte or lymphoblastoid cell cultures by Sendai virus induction. IFN-α subtypes with close structural similarity to the natural subtypes can be produced by recombinant DNA technology in cultured animal cells or in transgenic animals. The process for manufacturing a highly purified drug substance may consist of precipitations, filtrations and chromatographic steps. Purification methods of multicomponent IFN-α employing monoclonal or polyclonal antibodies have also been disclosed. The manufacturing process may contain additional virus inactivation steps, such as treatment with low pH and solvent/detergent treatment. IFN-α composition and methods for its production from human peripheral blood leukocytes are disclosed in, e.g. US Patents Nos. 5,503,828 and 5,391,713, the contents of which are herewith incorporated by reference.

A purification process yielding all major IFN-α subtypes is described in Example 2. Generally, it comprises, e.g., the step of contacting a solvent/detergent treated composition with at least two monoclonal mouse IgG antibodies having complementary subtype specificities in an immunoadsorption step. The α-interferon subtypes bound by the

monoclonal antibodies are eluted and the eluate is purified and filtered on a virus removal filter.

Other pharmaceutically useful proteins which can be subjected to virus removal filtration can be produced by methods known *per se*, for example by isolating from human or animal blood or by recombinant DNA technology in cultured cells or transgenic animals.

According to the present invention, a formulated protein solution is prepared by diluting a calculated amount of the purified biologically active protein with a formulation buffer containing polysorbate 80 or another non-ionic detergent in an amount, which gives a final concentration of 0.05 to 1 g/l, preferably about 0.1-0.5 g/l, of the non-ionic detergent. The degree of purity of the protein is advantageously at least about 90 %. The formulated solution may be prefiltered with a 0.04-0.2 μm filter and thereafter filtered with a virus removal filter having a preferred pore size of 10-40 nm. The non-ionic detergent does not cause any plugging of the filter and, depending on the molecular size of the protein, the filtration can be carried out with a constant pressure without any decrease in the filtrate flux and thus with high capacity and constant removability of viruses. Two virus filters may be used sequentially, which improves virus removal.

The recovered filtrate is filtered with a sterile filter and filled in vials, syringes or other containers compatible with parenteral injectables. It is also possible to carry out the virus filtration and sterile filtration in reversed order.

Included in the scope of a virus removal filter (nanofilter) are filters suitable for the removal of viruses from pharmaceutical proteins solutions. The size of the pores or perforations in the filter should be small enough to effectively remove even small non-enveloped viruses, such as parvoviruses. The proper pore size can be assessed by spiking experiments with model viruses, in which at least 4 log, preferably at least 6 log, of model viruses with a size of ca 20 to 40 nm should be removed. Based on such tests, the theoretical pore sizes of the virus removal filters can be estimated to be about 10 to 40 nm, preferably about 10 to 20 nm. In the present context, virus filters capable of reducing the concentration of model viruses at the above mentioned spiking tests with at least 4 log, are considered to have a "high virus retentive capacity". It is particularly important that the filters used have such capacity also in relation to small non-enveloped viruses.

The buffer of the liquid formulation is less critical and may be an inorganic buffer or

organic buffer. The pH of the buffer may be in the range of 4.5-7.5, and the buffer may contain other substances, e.g. inorganic salts, sugars, amino acids, polyols or cyclodextrins. Other stabilizers can be added to IFN-α solution after the virus filtration step.

The activity of IFN-α solution to be filtered with a virus removal filter may be close to that in the final product or it may be considerably higher. In the latter case, the solution is diluted after virus filtration. The activity of IFN-α in the final product is selected based on several variables, including the disease to be treated, therapeutic regimen and administration system. Generally, the activity of IFN-α solution before virus filtration is in the range of 3 to 50 mill. IU/ml.

Examples of non-ionic detergents to be used as a stabilizer include polyoxyethylene-based detergents, such as polyoxyethylene sorbitan monooleate (polysorbate 80), polyoxyethylene sorbitan monolaurate (polysorbate 20), polyoxyethylene lauryl ethyl (laureth 4) and polyoxyethylene, polyoxypropylene block polymer (poloxamer 188). Polysorbate, such as polysorbate 80 is most preferred. Polysorbate 80 as well as the other non-ionic detergents are used at concentrations in excess of the critical micellar concentration, in the case of polysorbate 80 typically about 0.05 to 1 g/l. A preferred range is 0.1-0.5 g/l, and most preferred concentration about 0.2 g/l.

According to a preferred embodiment the non-ionic detergent used has a low peroxide number, so as to prevent any harmful oxidation reactions in the pharmaceutical formulations. Preferably, the peroxide number is less than 5.0 mEq/kg tested according to Ph. Eur. 1997. Optionally, an antioxidant can be added to the formulation in order to prevent oxidation of IFN-α.

The following non-limiting Examples illustrate the invention:

Analytical Methods used in the Examples

IFN-α concentration

The IFN-α concentration was measured by a time-resolved fluoroimmunoassay (FIA) on microtitre plates. The IgG fraction of a bovine antiserum against human leukocyte IFN-α was used in capturing and a mixture of two Eu-labelled mouse IgG monoclonal antibodies to IFN-α for detection. The monoclonal antibodies were the same as used in the purification of IFN-α (Example 1). The details of the assay have been described elsewhere

(Rönnblom et al., APMIS 105, 531-536, 1997). IFN-α concentration was expressed as IU/ml using a laboratory standard, which was calibrated by the virus plaque reduction assay against the International Reference Preparation of Interferon, Human Leukocyte 69/19 (NIBCS, U.K.).

Interferon antiviral activity

The antiviral activity of the IFN was determined by a virus plaque reduction assay in 35 mm petri dishes using Human Epithelial 2 (HEp2) cells challenged with Vesicular stomatitis virus (VSV). The IFN-α samples, control and standard were diluted serially at 0.25 log intervals to concentration of 0.3-3 IU/ml in Eagle's Minimum Essential Medium (EMEM) supplemented with fetal calf serum (FCS) 7% and aureomycin 0.004%. The samples were assayed as triplicates at four dilutions in at least two assay series. One ml of cell suspension (2 x 10^6 cells/ml) in EMEM and 1 ml of sample dilution were added to dishes. Virus control dishes without IFN were included in each assay series. After incubation of overnight at 37 °C in 3-4% CO_2 atmosphere the solutions were removed from the confluent cell layers and 150-200 PFU of VSV in 1 ml of EMEM was added. After incubation of 40-45 min the virus was removed and cells were overlayed with 2 ml of agar 0.8% in EMEM. After overnight incubation the virus plaques were calculated. One unit of IFN activity is the highest dilution of the sample, which inhibits 50% of the virus plaques as compared to the virus control. Interferon activity was expressed in International Units (IU) using a laboratory standard, which was calibrated against the International Reference Preparation of Interferon, Human Leukocyte 69/19 (NIBCS, UK).

Total protein

Total protein concentration was measured according to Lowry using human albumin as a standard (Total Protein Standard, Finnish Red Cross Blood Transfusion Service, Helsinki, Finland).

Western blot

Sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) was performed by the method of Laemmli using 15% gels. Proteins were electroblotted to a nitrocellulose membrane, the membrane was blocked with 0.5% Tween 20 and washed with 0.05% Tween 20 in 0.011 mol/l sodium phosphate buffer, pH 7.0, containing 0.14 mol/l NaCl (PBS). The membrane was incubated with bovine polyclonal IgG against IFN-α (Wellcome Research Laboratories), 4 µg/ml in PBS containing 0.05% Tween 20 and 0.1% human albumin for 2 h at room temperature. The membrane was washed and incubated

with peroxidase-conjugated rabbit anti-bovine IgG (Jackson Immunoresearch Laboratories, PA, USA). After washing, the positive bands were visualized by using 4-chloro-1-naphthol as the peroxidase substrate.

Polysorbate 80

Polysorbate 80 concentration was measured by a colorimetric method (Milwidsky, Analyst 94, 377-386, 1969).

Example 1

Production of purified leukocyte IFN-α

This example describes the production of a high purity leukocyte IFN-α drug substance which was used in the stabilization and filtration examples (Examples 2-5).

The production of crude interferon was carried out in leukocyte cultures induced by Sendai virus essentially as described before (Cantell et al., Methods Enzymol. 78, 29-38, 1981). Residual cells in the culture supernatant were removed by microfiltration and the filtrate was concentrated 20-fold by ultrafiltration. The crude IFN concentrate was filtered through 1.2 µm and 0.22 µm filters and treated with 0.3% tri(n-butyl)phosphate and 1% polysorbate 80 for 16 h at 26 °C (solvent/detergent treatment). The solution was applied to an immunoadsorbent column containing two monoclonal antibodies against IFN-α coupled to CNBr-Sepharose 4FF gel. The monoclonal antibodies have complementary binding specificities and together bind all major IFN-α subtypes. The immunoadsorbent column was washed extensively and the bound IFN-α was eluted with buffer adjusted to pH 2. The eluate was neutralized and concentrated about 30-fold by ultrafiltration. The concentrated eluate was applied to a Superdex 75 gel filtration column equlibrated and eluted with PBS. The IFN-α containing fractions were pooled and the purified drug substance thus obtained was stored frozen at - 70 °C.

The purified drug substance was analyzed for IFN-α subtype composition by using procedures described in detail elsewhere (Nyman et al., Biochem. J. 329, 295-302, 1998). It was found to contain the subtypes α1, α2, α4, α7, α8, α10, α14, α17 and α21.

Example 2

Short term adsorption of purified multicomponent IFN-α onto glass from different formulations

Short-term stabilizing effect of various stabilizers was determined by assessing the adsorption of IFN-α onto glass.

Purified leukocyte IFN-α bulk drug was diluted in polypropylene vials to a final concentration of 3 mill. IU/ml (0.02 g/l) in PBS containing one of the following stablizers:

1. polyoxyethylene lauryl ether (laureth 4, Brij® 35, CAS-9002-92-0)
2. polyoxyethylene sorbitan monooleate (polysorbate 80, Tween® 80, CAS-9005-65-6)
3. polyoxyethylene, polyoxypropylene block polymer (poloxamer 188, Pluronic® F-68, CAS-9003-11-6)
4. human serum albumin

Laureth 4, polysorbate 80 and poloxamer 188 were used at final concentrations of 0.1, 0.2, 0.5 and 1.0 g/l. Albumin was added to a final concentration of 0.5, 1.0, 1.5, and 2.0 g/l. As a control, the IFN-α bulk drug was diluted in PBS. Samples were taken from the formulated solutions immediately after mixing for the determination of IFN-α concentration, and 100 µl of the formulated solutions were transferred into glass vials. The vials were kept for 20 h at at room temperature (23 °C). Samples were taken for IFN-α concentration determination. The results are shown in Figure 1. Adsorption was determined as the difference between the initial and final concentration of IFN-α in the vials.

About 30 % of IFN-α was adsorbed onto the glass vials in the absence of any stabilizer (Fig. 1). The stabilizers studied prevented the adsorption of IFN-α to a different extent. Polysorbate 80 was most effective followed by laureth 4, albumin and poloxamer 188.

Formation of IFN-containing aggregates was studied by Western blot analysis under non-reducing conditions. Highly purified leukocyte IFN-α was incubated in glass vials in PBS containing polysorbate 80 or albumin for 20 h at at 23 °C. Figure 2 shows the Western blot of the samples containing 0.1 g/l (lane 3), 0.2 g/l (lane 4), and 0.5 g/l (lane 5) of polysorbate 80, and 0.5 g/l (lane 6), 1.0 g/l (lane 7) and 1.5 g/l (lane 8) of albumin. Lanes 1 and 2 show negative and positive IFN-α aggregate controls, respectively. In polysorbate

80-containing solutions only bands corresponding to IFN-α monomers and dimer were seen. The intensity of the dimer band was weaker at polysorbate 80 concentrations 0.2 g/l and 0.5 g/l than at 0.1 g/l. In albumin solutions dimer bands were more intensive and additionally, bands with higher molecular weight corresponding to albumin-IFN complexes were seen. In polysorbate 80 formulations no bands corresponding to higher molecular weight complexes could be detected.

Example 3

Comparison of polysorbate 80 and albumin in the manufacture of virus-filtered and sterile-filtered multicomponent IFN-α solutions

Purified leukocyte IFN-α was diluted to the activity of 5 mill. IU/ml (40 μg/ml) in PBS containing either 0.2 g/l polysorbate 80 or 1 g/l albumin. The formulated solutions were prefiltered with a 0.1 μm filter and subjected to virus filtration by using Planova 15N filters (Asahi Chemical Industry Co, Japan). Filtrations were carried out in tangential flow mode at room temperature with a constant pressure of 0.8 bar. The system was pressurized with nitrogen gas. At the end of the filtration the virus filter was washed with formulation solution in the dead-end mode in order to recover all product from the filter system. Pressure, temperature and the mass of the filtrate were recorded during filtration. Samples were taken from the formulated solutions, after prefiltration, after virus filtration, and after sterile filtration for the determination of IFN-α concentration, polysorbate 80 and total protein and Western blot assay.

The results are summarized in Table 1 below and in Figure 3. Table 1 indicates the yield of IFN-α in the manufacture of a virus-filtered finished product by using polysorbate 80 (0.2 g/l) or albumin (1 g/l) as a stabilizer.

Table 1. Yield of IFN-α in the manufacture of a virus-filtered finished product calculated from IFN-α FIA results

Manufacturing step	Cumulative yield of IFN-α (%)	
	Polysorbate solution (n=3)	Albumin solution (n=3)
Formulated IFN-α bulk solution	100	100
Prefiltrated solution	99	97
Planova 15 filtrated solution	102	88
Sterile filtrated solution	101	89

As apparent from Table 1, the yield of IFN-α in the virus-filtered and sterile-filtered solution was consistently better in the presence of 0.2 g/l polysorbate than in the presence of 1 g/l albumin. Most of the IFN-α loss in albumin solutions took place during virus filtration, whereas there was no significant loss of IFN-α in polysorbate solution at the corresponding step. Notably, the recovery of polysorbate 80 was 99 % in filtrate of the virus filtration, indicating that there was no retention tendency of polysorbate during virus filtration. The recovery of albumin in the filtrate was 87% indicating that albumin was retented by the filter.

Figure 3 depicts Planova 15N filtration flow rates of purified IFN-α solutions stabilized by polysorbate 80 or albumin. Purified leukocyte IFN-α (40 μg/ml) in PBS containing 0.2 g/l polysorbate 80 (open circles) or 1.0 g/l albumin (closed circles) was filtered with Planova 15N filter at a constant pressure of 0.8 bar in tangential flow mode. The filtration rate remained constant in the presence of polysorbate 80 at least during filtration of 200 l/m^2, whereas it was reduced by about 80% in the presence of 1 g/l albumin already after filtration of 20 l/m^2. This indicates that the filter became plugged when albumin-containing solution was filtered, whereas there was no plugging tendency when polysorbate-containing solutions were filtered. The same results were confirmed by filtering pure albumin and polysorbate solutions (data not shown). Filtration of polysorbate-containing solution could be performed also in dead-end mode without any decrease in filtrate flow. Virus filtration did not cause any changes in the molecular weight distribution of IFN-α as analyzed by Western blot.

Example 4

Manufacture of a virus-filtered IFN-α finished drug stabilized with polysorbate 80

A formulated IFN-α bulk solution was prepared by adding to a suitable container PBS and polysorbate 80, mixing them, and adding purified multicomponent IFN-α so that the desired IFN-α activity was obtained in the calculated final volume of PBS containing 0.2 g/l of polysorbate 80. The formulated IFN-α solution was mixed carefully and prefiltered with a 0.1 μm filter. The prefiltered IFN-α solution was filtered through a virus filter (Planova 15N, Asahi) at a constant pressure of 0.9 bar in a dead-end mode. The filtrate was recovered and filtered with a 0.1 or 0.22 μm sterile filter and filled aseptically into the final containers.

Example 5

Stability of the virus-filtered IFN-α solution containing polysorbate 80

The stability of the virus-filtered IFN-α finished product manufactured according to Example 4 was studied at 6 °C and at 25°C up to six months. The results are given in Table 2.

Table 2. Stability of virus-filtered IFN-α solution stabilized with 0.2 g/l polysorbate 80

Time point (months)	IFN-α concentration mean ± SD (mill. IU/ml)		IFN antiviral activity mean ± SD (mill. IU/ml)	
	6°C	25 °C	6 °C	25 °C
0	4.5 ± 0.1	4.5 ± 0.1	4.0 ± 0.1	4.0 ± 0.1
1.5	4.6 ± 0.2	4.0 ± 0.1	4.5 ± 1.0	3.8 ± 0.0
3	4.5 ± 0.1	3.2 ± 0.0	4.3 ± 1.3	2.9 ± 0.5
6	4.3 ± 0.1	2.0 ± 0.0	4.4 ± 0.0	1.8 ± 0.2

As apparent from Table 2, no reduction in the immunochemical concentration and biological activity of IFN-α takes place during six months at 6 °C . A slight decrease (5-10 %) takes place at room temperature after storage for 1.5 months, and a decrease of about 30% is observed at room temperature after storage for 3 months. The results suggest good long-term stability for polysorbate-stabilized IFN-α solution stored at 2 to 8 °C.